CLAIMS

1. A discrete rotor position estimation method for a synchronized reluctance motor comprising:

sensing a d.c.-link voltage V_{dc} and a phase current I_{ph};

calculating a flux-linkage λ_{ph} of an active phase from the sensed d.c.-link voltage V_{dc} and the sensed phase current I_{ph};

comparing the calculated flux-linkage λ_{ph} with a reference flux-linkage λ_r, the reference flux-linkage λ_r corresponding to a reference angle θ_r which lies between angles corresponding to aligned rotor position and non-aligned rotor position in the synchronized reluctance motor; and

typically obtaining an estimated rotor position θ_{cal} equal to θ_r only once during the active conduction of a phase based on the comparison result when the calculated flux-linkage λ_{ph} is greater than the reference flux-linkage λ_r.

2. A discrete rotor position estimation method for a synchronized reluctance motor comprising:

sensing a d.c.-link voltage V_{dc} and a phase current I_{ph};

calculating a flux-linkage λ_{ph} of an active phase from the sensed d.c.-link voltage V_{dc} and the sensed phase current I_{ph};

comparing the calculated flux-linkage λ_{ph} with either two or three reference flux-linkages such as $\lambda_{r1}, \ldots,$

corresponding to reference rotor angles $\theta_{r1}, \ldots$ all of them lying between angles corresponding to aligned rotor position and non-aligned rotor position in the synchronized reluctance motor;

typically obtaining rotor positions $\theta_{cal1}, \ldots$ equal to $\theta_{r1}, \ldots$ based on the comparison results, twice or thrice during the active conduction of a phase when the calculated flux-linkage λ_{ph} is greater than the reference flux-linkages $\lambda_{r1}, \ldots$.

3. The discrete rotor position estimation method according to claim 1 or 2, further comprising modifying the estimated rotor position θ_{cal} with an incremental angle ϕ corresponding to the reference angle θ_r to obtain a more accurate estimated rotor position.

4. A discrete rotor position estimation method for a synchronized reluctance motor comprising:

sensing a d.c.-link voltage V_{dc} and a phase current I_{ph};

calculating a flux-linkage λ_{ph} of an active phase from the sensed d.c.-link voltage V_{dc} and the sensed phase current I_{ph};

comparing the calculated flux-linkage λ_{ph} with a reference flux-linkage λ_r, the reference flux-linkage λ_r corresponding to a reference angle θ_r which lies between angles corresponding to aligned rotor position and non-aligned rotor position of the synchronized reluctance motor; and

calculating an estimated rotor position θ_{cal} from

the calculated flux-linkage λ_{ph} using either one of the inductance model or the flux linkage model of the active phase, only once during the active conduction of a phase when the calculated flux-linkage λ_{ph} is greater than the reference flux-linkage λ_r.

5. The discrete rotor position estimation method according to claim 4, wherein the estimated rotor position is calculated at one PWM interrupt before the next phase is turned ON.

6. A discrete rotor position estimation method for a synchronized reluctance motor comprising:

sensing a d.c.-link voltage V_{dc} and a phase current I_{ph};

calculating a flux-linkage λ_{ph} of an active phase from the sensed d.c.-link voltage V_{dc} and the sensed phase current I_{ph};

comparing the calculated flux-linkage λ_{ph} with a reference flux-linkage λ_r, the reference flux-linkage λ_r corresponding to a reference angle θ_r which lies between angles corresponding to aligned rotor position and non-aligned rotor position of the synchronized reluctance motor; and

calculating estimated rotor positions either twice or thrice during the active conduction of a phase such as θ_{cal1}, ... from the calculated flux-linkage λ_{ph} using either one of the inductance model or the flux linkage model of the active phase, at every consecutive PWM interrupt when the calculated flux-linkage λ_{ph} is greater

than the reference flux-linkage λ_r.

7. The discrete rotor position estimation method according to any one of claims 1 to 6, wherein the reference flux-linkage λ_r at the reference rotor position θ_r is predetermined experimentally and is expressed as a polynomial expression of phase current I_{ph}. The reference rotor position θ_r is typically defined at any region near the mid-position θ_m of the aligned and the non-aligned position with a maximum deviation angle α_{max} of $30°$ electrical. The reference flux-linkage λ_r involving the polynomial expression in phase current I_{ph} is calculated within a processor.

8. The discrete rotor position estimation method according to claim 1 or 3, wherein the incremental rotor angle $\Delta\theta$ for every PWM interrupt is obtained only once from the knowledge of θ_{cal} during the active conduction of a phase when the calculated flux-linkage λ_{ph} is greater than the reference flux-linkage λ_r.

9. The discrete rotor position estimation method according to claim 2 or 5, wherein the incremental rotor angles such as $\Delta\theta_1, \ldots$ for every PWM interrupt are obtained either twice or thrice from the knowledge of $\theta_{cal1}, \ldots$ during the active conduction of a phase when the calculated flux-linkage λ_{ph} is greater than the reference flux-linkage λ_r, and the incremental rotor angles $\Delta\theta_1, \ldots$ are averaged to obtain the final incremental rotor angle $\Delta\theta$.

10. A discrete rotor position estimation method for a synchronized reluctance motor comprising:

detecting a phase inductance of the synchronized reluctance motor;

identifying an minimum region of the phase inductance during turn-on of an active phase;

determining a rotor position θ_{app} from the identified minimum region, as an estimated rotor position θ_{cal} and using it to calculate incremental rotor angle $\Delta\theta$ for every PWM interrupt.

11. A control method of a synchronized reluctance motor comprising:

obtaining the estimated rotor position θ_{cal} by the estimation method according to one of claims 1 to 6 and 9;

calculating an absolute rotor position θ_{abs} from the estimated rotor position θ_{cal} by adding a stroke angle of the motor;

determining the incremental rotor angle $\Delta\theta$ by processing an error between the absolute rotor position θ_{abs} and a finally estimated rotor position θ_{est} through either one of a proportional-integral (PI) control and a proportional control;

generating the finally estimated rotor position θ_{est} in every predetermined period by adding the incremental rotor angle $\Delta\theta$ to the finally estimated rotor position θ_{est} in the previous cycle; and

controlling turn-on and turn-off angles of each

phase based on the finally estimated rotor position θ_{est}.

12. A control method of a synchronized reluctance motor comprising:

calculating an incremental rotor angle $\Delta\theta$ by counting the number of PWM interrupts between two consecutive instants when the estimated rotor position θ_{cal} is obtained by the method according to one of claims 1 to 6 and 9;

generating delays to turn-off an active phase and turn-on the next phase, the delays normally defined with respect to the reference rotor position θ_r;

adjusting the delays with the estimated rotor position θ_{cal} to turn-off the active phase and turn-on the next phase; and

controlling a turn-on angle θ_{on} and a turn-off angle θ_{off} of each phase of the motor based on the incremental rotor angle $\Delta\theta$ and the adjusted delays.

13. The control method according to claim 11 or 12, further comprising

calculating a speed ω of the motor from the incremental rotor angle $\Delta\theta$ in a relatively slower timer interrupt compared to a PWM interrupt, and

varying continuously a turn-on angle θ_{on} and a turn-off angle θ_{off} of each phase of the motor based on the speed ω and the torque demand of the motor.

14. The control method according to claim 11 or 12, further comprising defining a timer interrupt faster than

the PWM interrupt for achieving the turn-on and the turn-off of each phase at any point in between two PWM interrupts.

15. A control method of a synchronized reluctance motor comprising:

monitoring continuously a peak of a phase current and a negative change rate of phase current in each phase; and

keeping the turn-off angle fixed, and advancing the turn-on angle so that a pre-determined peak phase current and a negative rate of change of phase current corresponding to the maximum torque are achieved.

16. The control method according to claim 15, wherein instead of monitoring the negative rate of change of phase current a lead angle ϕ between the peak current and the peak flux in each phase is monitored, to judge the maximum torque at the rated speed condition.

17. An apparatus for estimating discretely a rotor position for a synchronized reluctance motor comprising:

sensor operable to sense a d.c.-link voltage V_{dc} and a phase current I_{ph};

section operable to calculate a flux-linkage λ_{ph} of an active phase from the sensed d.c.-link voltage V_{dc} and the sensed phase current I_{ph};

section operable to calculate the reference flux-linkage λ_r from the polynomial expression in phase current I_{ph};

section operable to compare the calculated flux-linkage λ_{ph} with the reference flux-linkage λ_{r}, the reference flux-linkage λ_{r} corresponding to a reference angle θ_{r} which lies between angles corresponding to aligned rotor position and non-aligned rotor position in the synchronized reluctance motor; and

section operable to obtain an estimated rotor position θ_{cal} only once when the calculated flux-linkage λ_{ph} is greater than the reference flux-linkage λ_{r}.

18. An apparatus for estimating discretely a rotor position for a synchronized reluctance motor comprising:

sensor operable to sense a d.c.-link voltage V_{dc} and a phase current I_{ph};

section operable to calculate a flux-linkage λ_{ph} of an active phase from the sensed d.c.-link voltage V_{dc} and the sensed phase current I_{ph};

section operable to calculate reference flux-linkages $\lambda_{r1}, \ldots$ from the polynomial expression in phase current I_{ph};

section operable to compare the calculated flux-linkage λ_{ph} with reference flux-linkages $\lambda_{r1}, \ldots$ the reference flux-linkages $\lambda_{r1}, \ldots$ corresponding respectively to reference angles $\theta_{r1}, \ldots$ which lie between angles corresponding to aligned rotor position and non-aligned rotor position in the synchronized reluctance motor;

section operable to obtain rotor positions $\theta_{cal1}, \ldots$ based on the comparison result, twice or thrice when the calculated flux-linkage λ_{ph} is greater than the reference flux-linkages $\lambda_{r1}, \ldots$.

19. The apparatus according to claim 17 or 18, further comprising section operable to modify the estimated rotor position θ_{cal} with an incremental angle ϕ corresponding to the reference angle θ_r to obtain a more accurate estimated rotor position.

20. An apparatus for estimating discretely a rotor position for a synchronized reluctance motor comprising:

sensor operable to sense a d.c.-link voltage V_{dc} and a phase current I_{ph};

section operable to calculate a flux-linkage λ_{ph} of an active phase from the sensed d.c.-link voltage V_{dc} and the sensed phase current I_{ph};

section operable to calculate the reference flux-linkage λ_r from the polynomial expression in phase current I_{ph};

section operable to compare the calculated flux-linkage λ_{ph} with a reference flux-linkage λ_r, the reference flux-linkage λ_r corresponding to a reference angle θ_r which lies between angles corresponding to aligned rotor position and non-aligned rotor position of the synchronized reluctance motor; and

section operable to calculate an estimated rotor position θ_{cal} from the calculated flux-linkage λ_{ph} using either one of the inductance model or the flux linkage model of the active phase, only once when the calculated flux-linkage λ_{ph} is greater than the reference flux-linkage λ_r.

21. The apparatus according to claim 20, wherein the estimated rotor position is calculated at one PWM interrupt before the next phase is turned ON.

22. An apparatus for estimating discretely a rotor position for a synchronized reluctance motor comprising:

sensor operable to sense a d.c.-link voltage V_{dc} and a phase current I_{ph};

section operable to calculate a flux-linkage λ_{ph} of an active phase from the sensed d.c.-link voltage V_{dc} and the sensed phase current I_{ph};

section operable to calculate the reference flux-linkage λ_{r} from the polynomial expression in phase current I_{ph};

section operable to compare the calculated flux-linkage λ_{ph} with two or three reference flux-linkages λ_{r1}, ... the reference flux-linkages λ_{r1}, ... respectively corresponding to reference angles θ_{r1}, ... which lie between angles corresponding to aligned rotor position and non-aligned rotor position of the synchronized reluctance motor; and

section operable to calculate estimated rotor positions θ_{cal1}, ... either twice or thricefrom the calculated flux-linkage λ_{ph} using either one of the inductance model or the flux linkage model of the active phase, at every consecutive PWM interrupt when the calculated flux-linkage λ_{ph} is greater than the reference flux-linkage λ_{r1}, ...

23. The apparatus according to claim 17 or 20,

further comprising a section operable to estimate the incremental rotor angle $\Delta\theta$ for every PWM interrupt only once from the knowledge of θ_{cal} during the active conduction of a phase when the calculated flux-linkage λ_{ph} is greater than the reference flux-linkage λ_r.

24. The apparatus according to claim 18 or 22, further comprising a section operable to estimate the incremental rotor angles $\Delta\theta_1, \ldots$ for every PWM interrupt either twice or thrice from the knowledge of $\theta_{cal1}, \ldots$ during the active conduction of a phase when the calculated flux-linkage λ_{ph} is greater than the reference flux-linkage $\lambda_{r1}, \ldots$, and a section operable to average the incremental rotor angles $\Delta\theta_1, \ldots$ to obtain the final incremental rotor angle $\Delta\theta$.

25. An apparatus for estimating discretely a rotor position for a synchronized reluctance motor comprising:

section operable to detect a phase inductance of the synchronized reluctance motor;

section operable to identify an minimum region of the phase inductance during turn-on of an active phase;

section operable to determine a rotor position θ_{app} from the identified minimum region, as an estimated rotor position θ_{cal}; and

section operable to obtain the incremental rotor angle $\Delta\theta$ from θ_{app}.

26. An apparatus for controlling a synchronized reluctance motor comprising:

section operable to obtain the estimated rotor position θ_{cal} by the estimation method according to any one of claims 12 to 17;

section operable to calculate an absolute rotor position θ_{abs} from the estimated rotor position θ_{cal} by adding a stroke angle of the motor;

section operable to determine the incremental rotor angle $\Delta\theta$ by processing an error between the absolute rotor position θ_{abs} and a finally estimated rotor position θ_{est} through either one of a proportional-integral (PI) control and a proportional control;

section operable to generate the finally estimated rotor position θ_{est} in every predetermined period by adding the incremental rotor angle $\Delta\theta$ to the finally estimated rotor position θ_{est} in the previous cycle; and

section operable to control turn-on and turn-off angles of each phase based on the finally estimated rotor position θ_{est}.

27. An apparatus for controlling a synchronized reluctance motor comprising:

section operable to calculate an incremental rotor angle $\Delta\theta$ by counting the number of PWM interrupts between two consecutive instants when the estimated rotor position θ_{cal} is obtained by the method according to any one of claims 12 to 17;

section operable to generate delays to turn-off an active phase and turn-on the next phase, the delays normally defined with respect to the reference rotor position θ_r;

section operable to adjust the delays with the estimated rotor position θ_{cal} to turn-off the active phase and turn-on the next phase; and

section operable to control a turn-on angle θ_{on} and a turn-off angle θ_{off} of each phase of the motor based on the adjusted delays decided by the incremental rotor angle $\Delta\theta$.

28. The apparatus according to claim 18 or 19, further comprising

section operable to calculate a speed ω of the motor is calculated from the incremental rotor angle $\Delta\theta$ in a relatively slower timer interrupt compared to a PWM interrupt, and

section operable to vary continuously a turn-on angle θ_{on} and a turn-off angle θ_{off} of each phase of the motor based on the speed ω and the torque demand of the motor.

29. An apparatus for controlling a synchronized reluctance motor comprising:

section operable to monitor continuously a peak of a phase current and a negative change rate of phase current in each phase; and

section operable to keep the turn-off angle fixed, and advance the turn-on angle so that a pre-determined peak phase current and a negative rate of change of phase current corresponding to the maximum torque are achieved.

30. The apparatus according to claim 29, wherein

instead of monitoring the negative rate of change of phase current, the section operable to monitor monitors a lead angle ϕ between the peak current and the peak flux in each phase, to judge the maximum torque at the rated speed condition.

31. A motor drive system comprising a synchronized switched reluctance motor to provide a driving power to a compressor drive and driving the synchronized switched reluctance motor by the control method according to any one of claims 11 to 16.

32. An air conditioner comprising the motor drive system according to claim 31.